Office of the Secretary of Defense

REPORT TO CONGRESS

Department of Defense

DoD Renewable Energy Assessment

Final Report

14 March 2005

Executive Summary

The Department of Defense is pleased to submit this report to Congress, outlining a short- and long-term strategy that will increase DoD's use of renewable energy as well as provide a model for approaches by other government agencies.

The report responds to a Congressional request to DoD to conduct a cross-Service assessment of renewable energy alternatives at or near military installations (Senate Report 107-68). It was led by the Air Force, which formed a Renewables Working Group (RWG) for the assessment. The RWG comprised representatives from each of the Services, the U.S. Department of Energy (DoE) and DoE national laboratories, and the renewables industry.

We evaluated renewable resources on and near installations, developed purchasing strategies, evaluated the impact renewables have on energy security, and prepared a roadmap for the future. This report focuses on wind, geothermal, and solar energy, with the solar component including photovoltaic (PV), solar thermal, daylighting, and transpired heat collection. The latter technology is like a second skin for buildings and is used in colder climates to preheat ventilation air for buildings. Regarding these specific technologies, the study found that:

- Where economical, DoD should pursue on-installation production of renewable energy because it provides energy savings, reduces our dependence on foreign energy, and saves money, while increasing energy security.
    - There is good potential for wind projects where utility rates are high or where power is generated at remote sites and a wind-diesel hybrid can be developed.
    - Geothermal energy provides high-density power and there are a few potentially viable resources on DoD property. The Navy's China Lake, California, geothermal power plant is operational.
    - Solar photovoltaic (PV) is still very expensive but could be economical where there are very high utility costs, where state and Federal rebates and tax incentives are in effect, and/or where there are state mandates requiring utilities to provide power from PV.
    - The best solar potential is in daylighting, transpired heat collection, and solar thermal applications.
- Purchasing energy produced from renewable resources can provide the greatest source of renewable energy, but is difficult to do since each procurement has many complexities:
    - Goal is to purchase at or near current utility rates on a lifecycle cost basis.
    - Purchasing green attributes (Green Tags) instead of energy is the approach of many Federal agencies, but DoD's preference is to encourage purchasing the renewable energy itself when economical from a lifecycle perspective.
- Long-term aggregated purchases by region appear to be the best purchasing option, although some installations will find local opportunities that should not be overlooked:
    - Easiest to execute contracts in deregulated states.
    - Federal power marketers such as Western Area Power Administration (WAPA) and Bonneville Power Authority (BPA) can aggregate and deliver renewable power to their Federal customers within regulated states.
    - The Defense Energy Support Center (DESC) is also an important aggregator.
- Biomass—although not studied in depth—shows promise, especially in areas without other renewable resources, but needs low transmission costs and cooperative utilities. Lack of utility support (the norm) will force plants to be built on or adjacent to installations, requiring time-consuming and complex efforts by the military installation and supplier.

- There are few installations capable of supporting large utility-sized renewable systems.
- On-installation renewable energy production as well as some off-installation production contributes to the energy security of the installation if grid power is lost.

Although there has been a steady increase in DoD's use of renewable energy over the last few years, the strategies outlined herein lay the groundwork for greater gains in the future. General conclusions follow:

- The renewable energy industry continues to grow in capacity and is steadily improving technologies to enhance performance, rendering it increasingly cost-competitive. DoD can become the early market of choice, benefiting from these trends.
- Because long-term costs are predictable for renewable energy but not for fossil fuels, long-term contracts to purchase renewable energy will deliver cost stability and be a hedge against future energy price increases.
- Renewable energy technologies have the greatest potential in specific geographic regions and should be selected to optimize this potential.
- While the technologies assessed herein have proven dependable and cost-effective in appropriate situations, DoD is continuing its historic role as a catalyst for the development of other emerging renewable technologies.
- On-installation and, in certain cases, regional grid-level renewable energy production may improve energy security and be more cost-effective than conventional emergency power generation.

DoD has a long history of pursuing renewable energy to meet its energy needs. At the end of 2004, 2.5% of energy used by U.S. military installations came from renewable sources (6% if renewable power from pre-1990 plants and other sources are included). This percentage continues to increase as the performance of renewable energy technologies improves and costs are reduced. The renewable energy is a mixture of on- and near-installation generation and cost-effective long- and short-term renewable electricity purchases from third-party providers. While the current level of DoD's renewable energy use meets the Federal goal set by DoE, it only represents a small fraction of the possibilities. Attached to this report is an implementation plan describing recent renewable initiatives.

Our renewable energy vision is to maintain a commitment to renewable energy supported by a DoD-wide appreciation for the economic, environmental, and security benefits of renewable energy technologies. DoD's program includes:

- Financial support for implementing demonstrated, economical technologies that are especially applicable for DoD's energy needs.
- Sponsoring a wide variety of demonstration projects where compatible with the installation's mission and the rapid evolution of those projects to full-scale deployments.
- Continuing evaluation of renewable resource opportunities.
- Careful attention to lessons learned and the rapid dissemination of those lessons.
- Development and continued improvement of effective contracting vehicles.
- Innovative approaches for attracting private capital for on-installation development.
- Effective and continuing education of those having the responsibility for acquisition and management of energy and energy systems.

After significant on-installation evaluations, including emplacing wind metrology towers at twenty locations, geothermal studies, and developing software to analyze solar potential, the following possibilities exist:

- The final wind potential could be as much as 70 average megawatts (MWa) on 109 facilities. This is an optimistic projection since it represents the resource only. Factors such as economics, mission, and the environment have not been considered. (Note: Wind and solar produce power intermittently; thus 10 MW of capacity may only produce an average of 3 MW, therefore the term "MWa" meaning "megawatt average")
- Three installations assessed for geothermal power generation may offer a commercially viable resource with a fourth warranting further evaluation. Six to eight installations show some promise as a source of heating grade energy and merit further research.
- Four hundred thirty locations were evaluated for solar potential and at least one of the solar technologies evaluated (primarily daylighting) was feasible at most locations.

Although biomass was not a part of the study, we found many biomass energy opportunities, especially in locations where other renewable resources are limited. This is especially true in the Southeast region of the country where animal waste is extremely plentiful and has become an environmental liability. However, most states with the problem do not have deregulated utilities, making economical acquisition of the power challenging, yet still worth the effort.

Evaluation of on-installation resources did not identify large sources of renewable energy but nearly all installations could field some type of renewable project. On-installation presence of renewable projects is important for raising the energy awareness of personnel. There are a few installations with utility-grade wind, geothermal or solar resources, but these are the exceptions. While there are numerous opportunities for smaller-scale generation, it is through the purchase of commercially developed renewable energy where the greatest amount of renewable energy can be obtained. A number of purchasing strategies were developed and are currently being systematically tested. The goal is to purchase renewable energy at or near the price of conventional energy. This report covers a number of strategies but the primary focus is on using DoD's purchasing power to encourage development of renewable resources. One way to acquire renewable energy in the Federal government is through the purchase of renewable attributes called "Green Tags." This approach nearly always results in a surcharge on the cost of energy ranging from hundredths of a cent up to as much as 4 cents per kilowatt-hour (kWh). Although tag buys at low cost have a place in certain situations, DoD focuses on energy purchases where premiums are not required or where local circumstances justify a small premium.

Energy security requirements vary with installation missions. Studies were performed to evaluate the role renewables could play in energy security, especially wind and solar which by nature do not provide consistent output. It was found that renewables have the potential to provide added energy security when the source of generation is on the installation. Renewables in close proximity and which can be dedicated to the installation, especially when teamed with existing diesel power sources, can also contribute to energy security, although electric lines transmitting this power to the installation could be at risk. In some cases, where energy security needs are high, it could be more cost-effective to pay a slightly higher cost for renewable energy than to acquire more conventional alternatives.

TABLE OF CONTENTS

Introduction

Congress asked DoD to conduct a cross-Service assessment of renewable energy alternatives at or near military installations as described in Senate Report 107-68.

Additionally, the FY 2004 (MILCON) report provided the following guidance to DoD on renewable energy:

> ENERGY CONSERVATION INVESTMENT PROGRAM…The Committee also directs the Department to provide to the congressional defense committees a strategy and projected budget for implementing the findings and recommendations of the [final report to Congress] within 90 days after the completion of the report. The plan should include the following elements: a detailed budget proposal and timeline encompassing short term and long term objectives; management and personnel requirements to execute the plan in each of the Services; and an explanation of any changes needed in procurement, legal, or regulatory requirements to streamline the procurement of renewable energy at U.S. defense installations. The plan should also provide a detailed description of standardized processes and procedures to provide ongoing program support and address operational, environmental, cost, education, and technology issues.

The Air Force was designated as the lead component for the renewable energy assessment and formed a Renewables Working Group (RWG) to conduct the assessment. The RWG membership includes representatives from the Air Force, Army, Navy, Marine Corps, and the U.S. Department of Energy's (DoE) Pacific Northwest National Laboratory, National Renewable Energy Laboratory, Sandia National Laboratories, and Idaho National Engineering and Environmental Laboratory. Representatives from the renewable industry trade associations, DoE headquarters, and universities were also consulted and provided valuable contributions to the work.

In May 2002, DoD provided Congress with an interim report describing the scope of the renewables assessment and the intended analytical products.

Renewable Energy Can Serve the Military Mission

Executive Order (E.O.) 13123, *Greening the Government through Efficient Energy Management*, allows credits for renewable energy activity toward Federal agency conservation goals. The Administration's national energy plan, *Reliable, Affordable, and Environmentally Sound Energy for America's Future*, encourages development of renewable resources on Federal land. A finding of this report is that renewable energy, in some cases, can also serve and sometimes enhance the military mission. These contributions, while understood by military engineering personnel, are largely unknown to potential users in the larger military population.

Renewable energy can make a valuable contribution to flexible, reliable, and secure electricity supplies for military installations in specific locations. These findings are described in the "Renewables and Security" section of this report. Some renewable electricity contracts may also provide a hedge against rising electricity costs; these opportunities and the test case to lay an implementation path forward are described more fully in the "Purchasing Strategy" section of the DoD Renewable Assessment Implementation Plan. DoD has identified installations where renewable energy generation may be developed onsite, economically and consistent with the mission. Some renewable products and services may also help reduce the logistical requirements on military installations and ranges. These opportunities are described in the "On-Installation Resource Development" section of this report.

DoD Renewable Energy Goal

Near-Term Goals

E.O. 13123, *Greening the Government through Efficient Energy Management*, establishes energy efficiency goals for all Federal agencies and directs DoE to establish renewable energy goals. DoD has met DoE's currently specified renewable energy goal and is working with DoE to set a new goal for the future. This goal will further increase the use of renewable energy and will be incorporated into DoD instructions on energy policy and executed in collaboration between the Office of the Secretary of Defense (OSD) and the Services.

At this writing, the greatest potential for reaching a new goal is through short- and long-term purchase agreements. A key purchasing component is to supply loads aggregated across multi-Service installations in a regional market. The RWG concludes that by aggregating loads to increase the size of the projected power purchase, and by establishing standardized contract terms for up to twenty years, the military can obtain prices economically equal to or better than existing short-term contracts for conventionally generated electricity. While purchasing renewable energy supplants an equal amount of fossil energy it does not always lower an installation's energy bill nor provide secure, on-base power generation as does renewable energy produced on base. For that reason, an element of each goal also includes on-installation renewable projects where resource development is consistent with mission operations.

In the coming months, DoD will examine and verify the costs, benefits, and resources required for each option. The OSD will encourage the institutional changes necessary to accelerate the DoD's use of renewable energy, including electricity generated from renewable resources.

Long-Term Goals

Congress provided funds to assess wind, solar, and geothermal generation potential on military installations and to develop purchasing strategies for renewable-based generation from the private sector. In response, the RWG developed twenty individual purchasing opportunities for approximately ninety major installations in twenty-six states. Efficiency improvements in renewable technologies, rising prices in electricity markets, and additional utility deregulation will create increased opportunities in the future. Approximately 105 installations, mostly small in area, will undergo economic and mission evaluations to determine the potential for small wind projects. Three to twelve sites show some geothermal potential, and as many as 430 sites may have some potential for at least one of the commercial solar technologies the RWG found suitable for military use.

The Services are investigating other promising renewable technologies, including some with near-term potential for application on and near installations and in-theater. These include biomass, ocean-thermal, wave, and river-current technologies for coastal and riverside installations and a wide range of flexible solar technologies for use in the field. The military role in the United States is expanding in support of civilian homeland security protection and response activities. Force protection on installations is a necessary component of this support. The Services will continue to identify, validate, and test the full range of emerging renewable technologies that have the potential to support critical functions, improve installation perimeter security, and provide mobile power for first-responders and expeditionary forces in the field.

On-Installation Resource Development

Congress directed an assessment of wind, solar, and geothermal energy potential on U.S. military installations, and provided additional guidance during the assessment to accomplish the following:

- Evaluate the value of renewable electricity generation for installation security.
- Provide standardized rules and procedures for facilitating government/industry renewable energy partnerships on military property.

The RWG provided DoD with a roadmap that identifies where and how geothermal, wind, and PV electricity can best be generated on specific installations consistent with financing, environmental concerns, and mission constraints. From a pool of 900 installations covering 22 million acres with 280,000 buildings, the RWG, using the latest renewable energy resource data, selected a subset of installations for detailed installation-specific assessments. These included eighteen for geothermal assessment, seventy-five with high potential for wind development, and data to evaluate 430 sites for solar resources.

The geothermal assessments updated twenty-year-old resource data with the most recent scientific literature and information gathered during visits to selected sites. Site-specific wind data was collected at each of the most promising twenty sites; the remaining wind sites were assessed using historical data. The solar assessment included 430 major locations. Software was developed for the study to further narrow the large number of potential solar candidates. Site evaluations were performed on a sampling of those sites to validate the solar evaluation software. A small number of site-specific solar assessments are continuing, using funding provided by Congress to support this report and by DoE's Federal Energy Management Program (FEMP).

Findings

The installations assessed have the potential to generate between 37 and 210 average megawatts (MWa) annually by 2020, which could provide additional capacity equivalent to between 1% and 6% of DoD's current electricity use. The larger figure is a practical maximum since mission, environmental, and cultural issues must be considered in-depth.

1. Three out of the eighteen installations assessed for geothermal generation offer what might become a commercially viable resource, with a fourth needing more evaluation. Six to eight additional installations show hot water potential and merit further research.
2. The final wind resource potential, including small wind, could be up to 70 MWa at 109 facilities, although mission, environmental, and other limitations will significantly reduce this potential.
3. The potential for one or more types of solar projects exists at each of the 430 locations assessed. These projects covered 1) grid-connected PV systems; 2) hybrid diesel/PV for remote applications; 3) solar hot water for domestic use, process loads, and pool heating; 4) transpired heat collectors to reduce space heating requirements; and 5) daylighting to replace electric lighting in warehouses and hangar-type buildings. Fulfilling this potential requires significant subsidies from states and utilities.

Table 1 summarizes the electricity generation potential identified by the assessment.

Table 1. Summary of Findings

Finance Source	Wind		Geothermal		Solar PV		Solar Thermal	
	Sites	MWa	Sites	MWa	Sites	MWa	Sites	MWa
Third Party	2	60.9	4	40	38	56.5	N/A	N/A
MILCON (ECIP)	107	9.2	N/A	N/A	4	12.2	up to 430	25
Total	109	70.1	4	40	42	68.7	up to 430	25

N/A = not applicable
ECIP = Energy Conservation Investment Program

The actual electricity generation achieved will depend upon several factors, including the mission, resolution of some resource uncertainties, continued state and utility subsidies of solar projects, and the development of more effective third-party financing methods.

DoD's challenges in pursuit of on-installation renewable electricity generation include the following:

1. Access to third-party investment funds (such as provided by independent power producers [IPP]) is dependent on the quality of the energy source which may be better off the installation.
2. MILCON Energy Conservation Investment Program (ECIP) funding is available for renewable projects, but require greater investment than privately funded projects because the government cannot benefit from state and Federal tax incentives. Generation projects that support mission goals and cannot attract private funding should be funded as priority ECIP projects.
3. Electric utilities tend to increase tariffs and backup capacity costs for installations that self-generate part of or their entire load, often to the extent that the projects become uneconomical.
4. Renewable generation projects can conflict with existing and planned military land uses. Incompatibility with existing military operations is often clear and definitive. Compatibility with future land and air use is unclear; productive sites can lay dormant in anticipation of future land and airspace needs. Planning can be accomplished primarily through Geographical Information System (GIS) evaluations using data from this assessment.
5. On-installation development of renewable potential will advance planning and in-depth coordination with installation commanders. Because of the potential conflict with or impact of renewable projects on an installation's mission, development of certain projects may be dismissed as too difficult, not feasible, or not in the best interest of the government.
6. Many of the current Energy Savings Companies (ESCO) lack expertise and experience with renewable technologies, resulting in an underutilization of Energy Savings Performance Contracts (ESPC).

Financing Options

The economic feasibility of on-installation renewable generation depends on available financing. Three financing models were evaluated:

- The IPP model, where third-party developers construct, own, and operate power projects on DoD property for sale to the grid on a wholesale basis.
- The Independent Energy Provider (IEP) model, where third-party developers construct, own, and operate power projects on DoD property for retail sale to the installation.
- The ECIP, a line item in the Military Construction Appropriation.

The IPP and IEP models are viable third-party financing options. The IPP approach is widely used but restricted to the sale of power to competitive wholesale power markets rather than to retail customers. The IEP concept, as conceived by the RWG for this analysis, is a variation of the IPP model that provides retail power to the installation. The IEP model may improve project economics if the project can combine the benefits of a large captive electrical load, the credit-worthiness of the U.S. Government, and tax incentives available to private developers. The IEP concept is now being tested at a Western Air Force base.

Aligning the three alternative financing models against the commercially viable renewable generation projects identified in this assessment, the RWG finds the following:

- The geothermal projects can/should be funded through the IPP or IEP models.
- Two of the potential wind projects may be profitable enough to attract IPP implementation; the rest could be developed under IEP or ECIP.
- The solar projects are not as easily categorized because local rebate and tax incentive programs are critical to project economics. The analysis found that PV and solar thermal (including daylighting) projects could supplant about 37 MWa or roughly 1% of DoD's U.S. electricity under ECIP funding alone. An additional 57 MWa, for a total of 94 MWa—2.6% of total consumption—could be financed if private sector investments were available. Most of the potential lies in grid-connected solar PV projects in states that currently have generous solar incentives.

Renewables and Security

On-installation renewable power generation can contribute to installation energy security when the generation provides continually available power or seamlessly provides backup power. This can be accomplished through renewable power alone at a handful of installations with excellent resource potential. It may also be accomplished on a much larger number of installations when renewable generation is used in combination with the standard complement of backup diesel generators. Use of renewable resources to power remote facilities and installation perimeter security devices can also significantly improve installation security.

Combining Renewable Power with Diesel Generation on Installations

Economic analysis supports on-installation power generation from renewables. Detailed analyses show that power generated from geothermal, wind, or a combination of wind and solar resources is frequently less expensive on a simple payback basis than additional (equivalent) supplementary diesel generation. This is largely because renewable sources also provide no-cost energy when there is no emergency and backup generators lie dormant. Over time, these renewable investments provide a pay-back whereas conventional diesel generation just continues to accumulate cost.

The intermittent nature of wind and solar energy and the distance they are removed from the critical load currently prohibit direct replacement of diesel generators. However, renewable generation equipment can be coordinated with diesel generators in two ways. First, output can be used to relieve the continuous demand on backup diesel, lengthening the time diesel generators can operate without refueling or maintenance. Second, renewable generation can increase the total power available on the installation, expanding the facilities and operations that can be served simultaneously during a grid outage.

The specific role of any renewable power generation will depend upon its nature (e.g., continuous geothermal versus more variable wind and solar generation), the renewable resource diversity provided by the installation's geography, and the unique installation demand characteristics. Simulations of various combinations of renewable and backup diesel generation demonstrate that the intermittency of both wind and solar resources presents complications but does not prevent them from serving as important energy security components. A cost-effective mass energy storage medium—possible in the near future given the amount of research and development currently being invested by DoE and industry—may make the intermittency of renewable energy irrelevant and allow renewable energy sources to become direct substitutes for diesel generators. Given the lack of emissions, renewable emergency power sources are also environmentally preferable. However, there is no blanket recipe for renewables to support energy security—the role of available renewable resources must be specifically designed for each installation.

Micro-Grids

Recent major grid failures and the vulnerability of the grid to terrorist actions have caused an increase in interest in energy security for DoD installations. One way to reduce the effect on an installation is the development of micro-grids. A micro-grid is the interconnection of modular generation sources to a distribution system serving a specific set of loads. The micro-grid is part of the main power network that can be operated autonomously when the main grid is down to continue to provide uninterrupted power to critical interconnected loads.

One way DoD facilities can address increased reliability needs is through micro-grids that include both on-installation and, in some cases, near-installation generation resources, including renewable resources.

If local utilities and the Services work together to develop resources across installation boundaries or adjacent to an installation, local energy security and reliability may be significantly improved, benefiting utility providers, military customers, and the surrounding community.

Energy Security Assessment

The energy security assessment evaluated whether using renewable energy has the potential to enhance supply reliability and overall security at military installations. In general, if renewable resources are to provide reliable power and heat for installations, they must be compatible with mission activities, affordable, and available during grid outages and other regional energy emergencies. The energy security benefits of renewable generation were evaluated by measuring their contribution during a simulated grid outage of up to 30 days at an operating military installation. The installation analyzed has a base load of 13 MW and a peak demand of 20 MW. Like many installations, it has emergency back-up diesel generators sufficient to provide power for 20% of its peak demand for up to two weeks. In the event of a planned terrorist act or a major natural disaster, a longer outage could occur. Such an outage would affect natural gas and diesel fuel resupply, making it important to stretch the availability of the diesel generators. Outages of up to 30 days were simulated using backup power from diesels and/or renewables sufficient to supply 10 MW of power more or less continuously. Power output from renewables and/or supplemental diesel generators operating with existing diesel generators was simulated against installation loads. The costs and benefits of each option were compared over a twenty-year period.

Findings

When operated with emergency diesel generators, as little as 5 MW of wind, solar photovoltaics, and/or geothermal power extend an installation's ability to continue its mission during simulated outages. Ancillary findings include the following:

- The variability of renewable energy does not diminish electricity reliability because the output from intermittent renewable generation (e.g., wind and solar) is largely predictable and can be managed by coordinating the operation of backup diesel generators. It is also possible to store excess energy when renewable power output is high.
- In some cases, an installation can depend on nearby generation, including renewable energy for its backup energy supply where the utility has the capability of segregating its service area from outside influences. This creates self-sustaining regional "islands" which should not be overlooked as installations engage in emergency planning to serve critical installation functions. Planning must necessarily be coordinated with regional energy suppliers, transmission companies, and major energy users.
- Clean air regulations do not restrict renewable hours of operation. Renewable power may be more reliable during routine or prolonged power outages than conventional diesel generators, which may have restricted hours of operation.

Comparative Cost Findings

DoD analyzed the economics of renewable systems using conventional payback models and energy consumption and power plant simulation tools. The performance and cost of renewable deployment and baseline diesel backup systems were based on operating facilities and installation records.

On-installation and near-installation generation options were considered.

Although more costly to install than backup diesel generators, renewable energy systems can provide reliable and economical backup power for military installations. The financial benefit stems from their continuing power production which reduces power purchased from the grid and frequently lowers the demand charge; this more than offsets their higher initial cost. The findings for specific configurations are:

- *Geothermal Power Plants.* The per-kilowatt capital cost for a geothermal plant is significantly higher than that of backup diesel generators. However, the continuous, reliable power supplied by the geothermal plant will result in rapid payback and a net benefit (over twenty years) of five times its incremental investment cost.
- *Wind Power Plants.* The per-kilowatt capital cost for wind power is about three times that of backup diesel generators. The predictable power supplied by the wind plant results in acceptable payback and a net benefit (over twenty years) of about one and one-half times its incremental investment cost.
- *Hybrid Wind/Solar Power Plants.* The per-kilowatt capital cost of a hybrid plant is about nine times that of backup diesel generators. The value of the predictable power from this hybrid plant will pay back the incremental investment cost within the twenty-year analysis period.
- *Solar Power Plants.* The per-kilowatt capital cost of a solar deployment is about ten times that of backup diesel generation. In an analysis at a California installation, the pure solar deployment did not pay back within the twenty-year analysis period.

This payback analysis is based on commercial investment costs and excludes government financial incentives. Including these incentives would significantly improve the performance of each renewable project, potentially making the pure solar option cost-effective.

Next Steps

These key steps should be taken to validate, extend, and implement findings:

1. DoD is considering options to accomplish a pilot project to test the above analysis. Based on the results, DoD will recommend strategies to the Services that incorporate renewable energy.
2. Based on the results of step 1, encourage installations to evaluate renewable energy alternatives as part of contingency planning for grid outages. Planning should be done regionally, include regional utilities and suppliers, and consider the use of the installation's renewable energy capacity as part of a local islanding strategy.
3. Replicate the successes of pilot projects at other military installations with full-scale development of on-installation or nearby renewable resources.

Critical Functions, Perimeter Security, Remote Facilities, and Combat

DoD is exploring multi-functional use of several renewable technologies that could simultaneously serve installations, force protection, remote power on ranges, and the expeditionary force (base forwarding and combat uses.) For example, Air Force installations and

readiness offices are collaborating with military laboratories and the Center for Army Analysis to determine how wind and solar products can support installations and help minimize logistical support requirements in-theater. Military transformation plans state:

> …the U.S. must prepare for new forms of terrorism…information attacks on its networks, cruise and ballistic missile attacks on its forces and territory, and attacks by chemical, biological, radiological, nuclear, or high-explosive (CBRNE)-armed adversaries. It must also cope with the unique demands of peace operations, homeland security, urban operations, and low-intensity conflicts. To deal with this new security environment…the US military must be able to conduct operations effectively across the entire spectrum of conflict against a broad range of potential adversaries… (with processes that achieve and maintain) advantage through changes in operational concepts, organization, and/or technologies that significantly improve its war fighting capabilities or ability to meet the demands of a changing security environment.

Some remote installation energy requirements currently being evaluated for renewable energy applications by the Army are listed in Table 2.

Table 2. Remote Missions on Military Installations

Installation Mission Using Renewables	No. of Sites
Air Quality Survey Stations	10
Landfill and Landfill Monitoring Stations	3
Radio Repeater Sites	7
Weather sites	12
Remote Site Lighting	8
Target Support	1,900
Town MOUT	1
Chemical Factory MOUT	1
Airfield MOUT	1
Tunnel Complex MOUT	1
Communications Facility MOUT	1
Fortress MOUT	1
Forward Operating Bases	5
Homeland Security (e.g., remote video monitoring, gate guard lighting)	20
Test Instrumentation Shelters	17

MOUT = Military Operations on Urban Terrain

These activities were drawn from Yuma Proving Ground, Arizona; White Sands Missile Range, New Mexico; Yakima Training Center, Washington; Pohakoloa, Hawaii; Fort Bliss, Texas; Fort Irwin, California; and Fort Lewis, Washington. Some installations have more or fewer sites than indicated, depending on mission. Renewable uses in combat are varied and cover watts to kilowatts. Typical deployed military missions being supported today or are in the planning stages include renewable power for tactical operations centers, hospital units, forward operating bases, and provisional response teams.

Conclusions

Renewable energy can assist military installations in meeting efficiency goals set by Congress and the Administration (e.g., E.O. 13123) and aid in exceeding them. Renewable energy sources may also provide DoD installations with environmental benefits such as reduced emissions.

DoD has used renewable energy in small amounts for several decades; approximately 2.5% of DoD's electricity supply now comes from renewable energy (6% if renewable power from pre-1990 plants and other sources are included). Growing competitive markets, rising fuel costs, energy reliability challenges, increasing renewable product performance, and the requirements of E.O. 13123 provide incentives to substantially increase DoD's use of renewable energy.

As the renewable energy industry grows, the performance of renewable energy technologies will continue to improve. Because the price of power from conventional sources continues to rise, the opportunity for cost-effective renewable energy supply will become greater and more geographically widespread. DoD can benefit from these trends by serving as the early market of choice for renewable energy providers, establishing streamlined procurements, and providing equipment manufacturers with sustained markets that allow economies of scale to further reduce the cost of renewable energy products.

Wind, solar, geothermal, and (to some extent) biomass provide the greatest potential in specific geographic regions, and the most cost-effective generation facilities will be located in these regions. These resources are not point sources, but rather distributed resources that may cover parts of an installation and surrounding lands. Hence, the identification of optimal deployment sites and the integration of these resources into the regional electricity grid are best accomplished cooperatively by all interested partners. DoD installations must actively seek the cooperation and participation of neighbors (suppliers, energy transmitters, and large energy users) in larger-scale renewable energy electricity purchases.

On-installation and/or regional grid-level renewable energy production may improve energy security at DoD facilities under some circumstances, and could be more economical on a lifecycle basis than backup diesel generators.

Identifying and developing renewable energy potential is an ongoing effort as technology continues to evolve and become more economical. The potential identified through this assessment effort must now be examined on a case-by-case basis. Where there is no conflict with installation mission or land use, projects must be planned and designed to maximize return on investment. The planning process will determine which projects warrant further consideration and eventual execution.

Acknowledgments

Air Force Civil Engineer Support Agency
- Col Josuelito (Joe) Worrell
- Col Jeffrey Leptrone
- Col Michael C. Cook (ret)
- Alvin L. Day
- Mike Santoro
- Gueta Mezzetti
- Lt Col Bill C. Wells
- Lt Col Robert Mitchell

Office of the Secretary of Defense
- Dr. Get Moy
- Cmdr Rob Tomiak

Army Assistant Chief of Staff for Installation Management
- Henry Gignilliat

Naval Facilities Engineering Command
- Bill Tayler

U.S. Navy Geothermal Program Office
- Frank Monastero

Headquarters, U.S. Marine Corps
- Carl Zeigler

Naval Air Warfare Center, Weapons Division
- Charles C. Combs

National Renewable Energy Laboratory
- Jeffrey Dominick
- Ed Cannon

Pacific Northwest National Laboratory
- Mike Warwick
- Michael C. Baechler
- Linda J. Sandahl

Sandia National Laboratories
- Dave Menicucci
- Bill Black

Idaho National Engineering and Environmental Laboratory
- Gary Seifert

Global Energy Concepts
- Karen Conover
- Kevin Smith